Jurnal
Teknologi

Full Paper

A REVIEW OF CHEMICAL AND PHYSICAL PROPERTIES OF COCONUT SHELL IN ASPHALT MIXTURE

Tay Lay Ting[a], Ramadhansyah Putra Jaya[a*], Norhidayah Abdul Hassan[a], Haryati Yaacob[a], Dewi Sri Jayanti[b], Mohd Azreen Mohd Ariffin[c]

[a]Department of Geotechnics and Transportation, Faculty of Civil Engineering, Universiti Teknologi Malaysia, 81310 UTM Johor Bahru, Johor, Malaysia
[b]Faculty of Agriculture, Department of Agricultural Engineering, Universitas Syiah Kuala, 23111 Darussalam, Banda Aceh, Indonesia
[c]Department of Structure and Materials, Faculty of Civil Engineering, Universiti Teknologi Malaysia, 81310 UTM Johor Bahru, Johor, Malaysia

Article history
Received
30th April 2015
Received in revised form
9th August 2015
Accepted
1st October 2015

*Corresponding author:
ramadhansyah@utm.my

Graphical Abstract

Abstract

Coconut shell is an agricultural waste which is abundant to the environment and also rise the risk to health as well as environment. Currently, most of the researchers are investigate the use of waste material which can reduce the costof construction and increase the strength. Some of thewaste materials are used in construction for instance palm oil fuel ash, rice husk, fly ash slag, sludge, coconut shell and etc. Hence, coconut shellwas selected for this study. Generally, the chemical and physical properties of coconut shell in road construction was highlighted in this paper and compared with others raw materials. In addition, the chemical and physical characteristics of coconut shell was presented according to X-ray Fluorescence (XRF), Scanning Electron Microscopy (SEM),Fourier Transform Infrared Spectroscopy (FTIR) Analysis and X-ray Diffraction (XRD). A review of using coconut shell in asphalt mixture has better potential than others raw materials to constribute in construction field.

Keywords: Coconut shell, SEM, XRD, XRF, FTIR

1.0 INTRODUCTION

Coconut has grown in more than 93 countries and one of the origin countries is South East Asia [1]. Coconut shell (CS) is one of the main polluter that contributes to the world's pollution trouble as it is a solid waste in form of shell with approximately 3.18 million tonnes annually, which represent over 60% of national waste volume [2]. Coconut shell, has cause copiously obtainable agricultural waste from local coconut industries [3].

Coconut shell is bio waste as others such as bamboo, jute, hemp, oil palm shell and rice husk have great potential as reinforcement in thermoplastics [4-6]. These bio wastes have contributes many environmental advantages like low density, low cost, lower pollution, good thermal properties, high toughness, reduced tool wear and biodegradability over traditional reinforcing filler such as glass and carbon [7-15].

Besides that, coconut shell also categories as Metal matrix composites (MMC) with fly ash and rice hush which can ameliorate characteristics such as great precise strength, precise modulus, good weather resistance and great damping capacity contrast to unreinforced alloys [14, 16-17]. Coconut shell ash and rich husk ash [16-20] also are the cheaper and low density reinforcement as solid waste by-product.

These advantages can make CS become a very important agricultural product around the world as the new source of energy-biofuel [2, 21] rather than burnt to produces CO_2 and methane emissions [21].

Dried CS contains 33.61% cellulose, 36.51% lignin, 29.27% pentosans and 0.61% ash [22]. CS has low ash content but high volatile matter, 65-75% [23]. The water absorption of the CS is higher than usual aggregate, which is 24% compared to 0.5 [1]. According to Madakson[24], coconut shell ash can hold out working temperature of 1500°C without load [16, 18-20]. Besides, CS is also more resistance against crushing, impact and abrasion compared to others conventional crushed granite aggregate[22].

Figure 1 shows the coconut shell that can found in the market and the crushed coconut shell that normally used in the test. It can use to mix with asphalt mixture directly for the experiment except water absorption test [22, 25]. CS has high water absorption ability because of its open structure containing many hydroxyl and acetyl group hence hemicelluloses can partly soluble in water and hygroscopic [26].

In order to reduce the water absorption ability of CS as the excessive content of water will weaken the structure of CS [27], chemical treatment can optimize the interface of CS to reduce its hydrophilic. The most usual treatment for CS is by using Sodium Hydroxide (NaOH) as it can reduce the hydroxide (OH) compound in CS hence reduce absorption ability [28-29].

CS -OH + NaOH => CS-O-Na+ + H2O

Besides that, some researchers have burnt CS into charcoal form and used as a filler to resist resistance to freezing, crushing and absorption [30].

(a) (b)

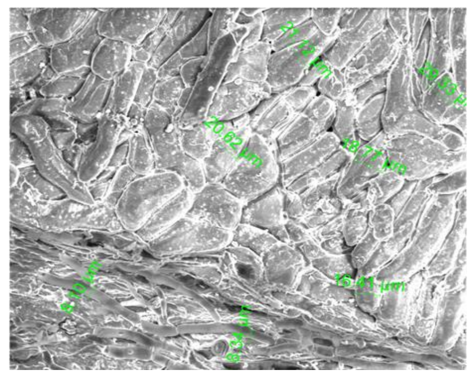
Figure 1 (a) coconut shell and (b) Crushed coconut shell

2.0 RESEARCH FINDINGS

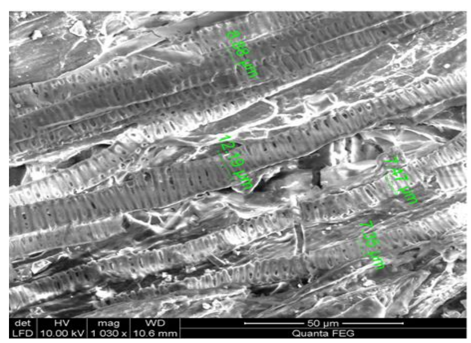
Microstructure is pointed to the material that has appereance on nm-cm length scale. Some microscopy techniques can be used to observe microstructure. The microstructural features of a given material may vary greatly when observed at different length scales. Microstructure analysis such as X-ray diffraction (XRD),scanning electron microscopy (SEM), Transmission electron microscope, and Energy dispersion X-ray microanalysis (EDX), Brunauer–Emmett–Teller (BET) surface area and Fourier transform infrared spectroscopy (FTIR) can be used to observe the structure of a material in a nano scale. Coconut shell ash (CSA) is the product of coconut shell powder that has packed in a graphite crucible before fired in electric resistance furnace at temperature of 1300°C.

2.1 Scanning Electron Microscopy (SEM)

From K. Gunasekaran *et al*., [1] Scanning Electron Microscope (SEM) fit with an Oxford INCA Energy Dispersive Spectroscopy system. The test has done at an accelerating voltage of 5 to 20 kV [15]. The SEM analyses have done on discrete cells of CS and continuous cells of CS. Figure 2 shows the results that CS have very closely spaced discrete cells which are 16.36 µm and 29.33 µm and the micro-pores were with sizes between 760 nm to 1.64 µm. Besides that, CS with continuous cells has various widths which are between 7.35-8.88 µm and its thickness is in range of 852.7 nm to 1.24 µm. All the results show that CS specimens can resist higher load, endure high crushing and abrasion resistance.



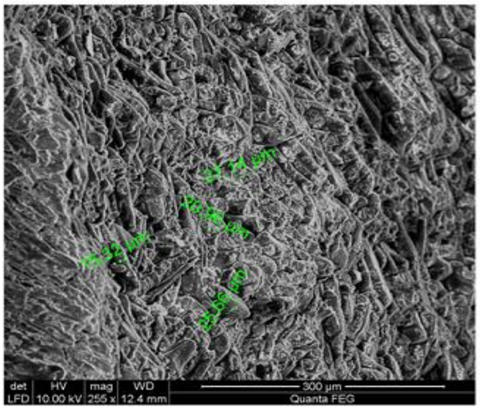
(a)



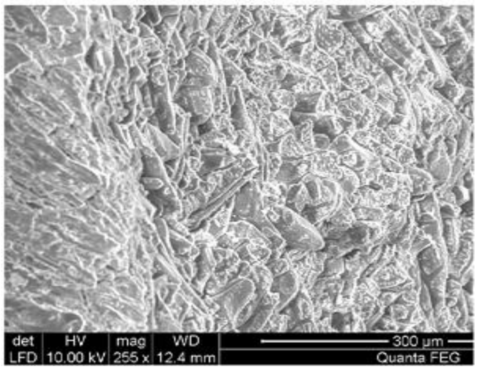
(b)

Figure 2 SEM images on CS specimens: (a) discrete cells of CS and (b) continuous cells of CS.

Besides that, the result from the Gunasekaran[1] in Figure 3(a) and 3(b) which is the CS specimens with soaking and without soaking. Figure 3(b) shows that CS has high water absorption ability as it absorbs water and stored as the pore structures inside the CS comport like a reservoir.



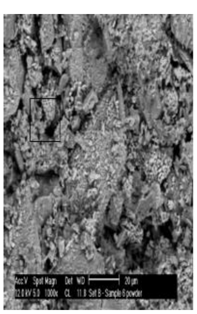
(a)



(b)

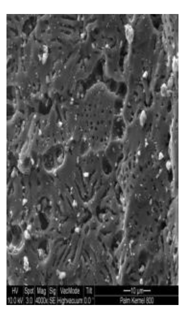
Figure 3 SEM Images on CS specimens: (a) without soaking and (b) with soaking.

Figure 4 is the SEM analysis to show the differences between the raw materials coconut shell ash, rice husk ash (RHA) and oil palm shell. The results show that RHA contains many crystalline grains which proved that many pores present in the material's structure by the formation of white colour minera [24, 31]. However, palm kernel shell ash just has minor crystalline grains formed and contains rough and porous surface and its structure is quite inhomogeneous. SEM analysis for the CSA was observed that its structure is solid in nature but irregular in size.



(a)

(b)



(c)

Figure 4 SEM image: (a) Coconut shell ash; (b) Rice husk ash and (c) palm kernel shell ash

2.2 X-Ray Fluorescence (XRF)

Mini Pal compact energy dispersive X-ray spectrometer (XRF) was used to do materials' elemental analysis which was controlled by a PC running the dedicated Mini Pal analytical software [18, 24]. The result of comparison between CS, rice husk and palm kernel shell is from Ghani *et al*. [31] and Madakson *et al*. [24]. Table 1 show the highest compound of CS is SiO_2 but still lower than rice husk. However, CS is hard because it contain high percentage of alumina, silicon oxide and iron oxide which are acknowledged to be among the strongest materials while others two samples although have high contain of silicon oxide, it still weaker than CS because of low contain of iron oxide and alumina.

Table 1 Element compound of rice husk, palm kernel shell and coconut shell

Compound	Percentage (%)		
	Rice husk	Palm kernel shell	Coconut shell
SiO_2	89.57	31.73	45.05
Al_2O_3	1.32	3.46	15.6
Fe_2O_3	1.43	1.78	12.4
P_2O_5	1.04	2.57	-
CaO	0.77	20.27	0.57
TiO_2	1.01	12.39	-
MgO	0.76	1.01	16.2
Na_2O	1.15	1.38	0.45
K_2O	1.65	1.51	0.52
Cl	1.3	0.08	-
MnO	-	1.27	0.22
C	-	12.55	-
ZnO	-	-	0.3

2.3 X-Ray Diffractometer (XRD)

The chemical composition of the phase in CSA was determined using Philips X-ray diffractometer. The X-ray diffractograms was taken using Cu Ka radiation at scan speed of 3o/min. Compound of CSA is SiO_2 and the elements present in it are C, Mg, O, Al,Fe, Si, Zn, Na and K which shows that the ash does not contain radioactive materials like Dy, Xe, Pr and Eu. The result of XRD as illustrated in Figure 5 is in correspondence with the result of XRF obtained.

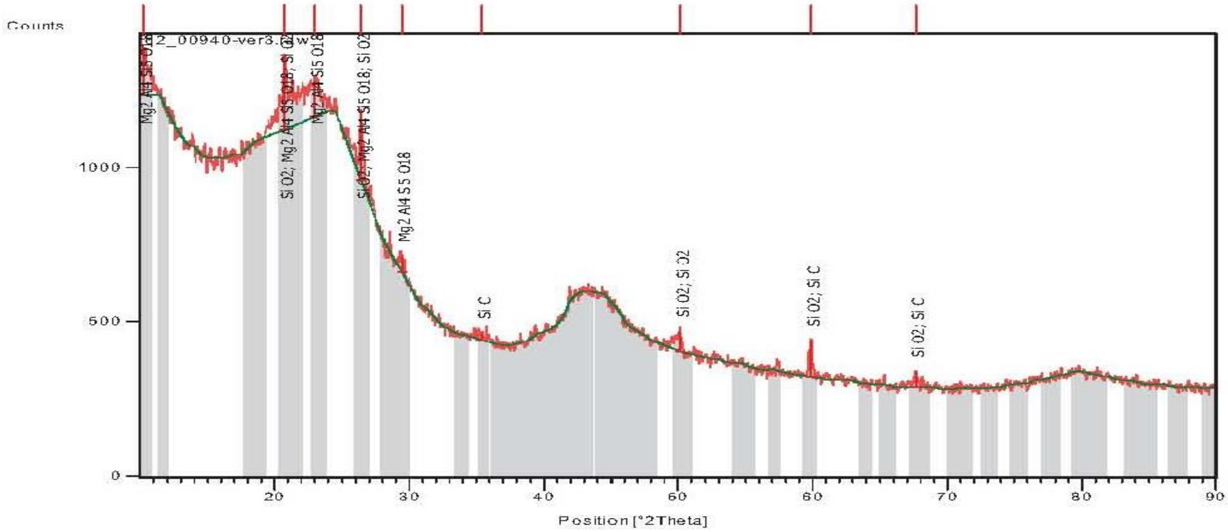


Figure 5 XRD pattern of coconut shell ash

2.4 Fourier Transform Infra-Red (FTIR)

Coconut shell ash was using FTIR-8400S Fourier transform infrared spectrophotometer (SHIMADZU) to test its functional groups present. The Figure 6 shows that IR spectrum rises because of the presence of quartz in the original ash series of bands located at 1132 and 443.64 cm^{-1} [24]. The series of bands at around 3797 cm^{-1}show the present of mullite while the series of bands at around 4091.15-4617.74 cm^{-1}show the present of carbon group. Mullite, Quartz, carbon and vitreous phases are confirmed presence because of the series of bands of mullitle, glassy and Quartz phase of the ash intersect in the area between 1220 $cm^{-1}$and 1434.12cm^{-1} [24]

Coconut shell ash was using FTIR-8400S Fourier transform infrared spectrophotometer (SHIMADZU) to test its functional groups present. Figure 6 shows that IR spectrum rises because of the quartz in the archetype of original ask series of bands placed at 1132 and 443.64 cm^{-1} [24]. The series of bands at around 3797 cm^{-1}show the present of mullite while the series of bands at around 4091.15-4617.74 cm^{-1}show the present of carbon group. Mullite, Quartz, carbon and vitreous phases are confirmed presence because of the series of bands of mullitle, Quartz and the glassy phase of the ash intersect in the region among 1220 $cm^{-1}$and 1434.12cm^{-1} [24].

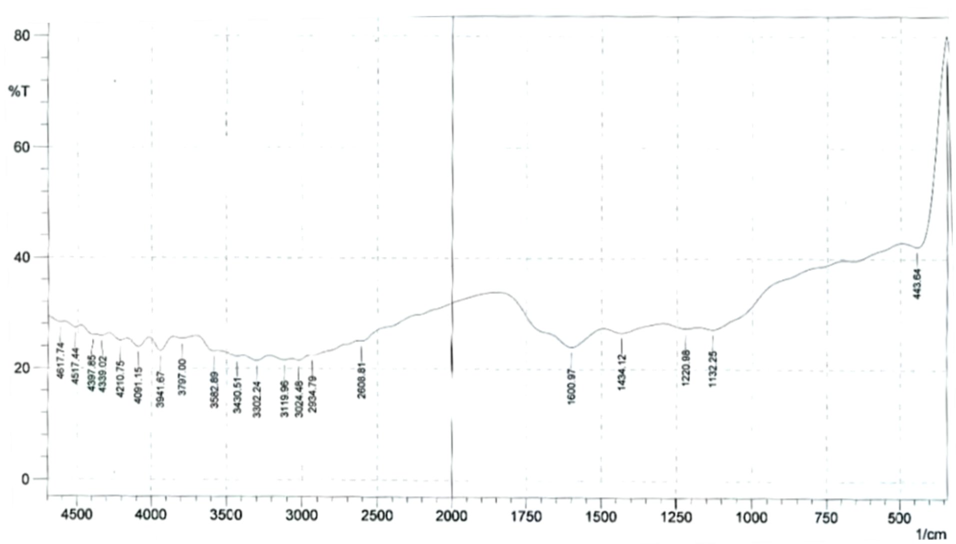


Figure 6 FTIR pattern of coconut shell ash

3.0 DISCUSSION

From the research findings above, the coconut shell ash can be observed and concluded that it is stronger than rice husk ash and palm kernel shell ash. Besides that, its characteristics are qualitified to used as metal matric composites in the civil field which that the Quartz, carbon phases and Mullite are present in it. The possibility to convert the coconut shell to a useful material are environmental friendly and constribute in construction field.

Acknowledgement

The support provided by Malaysian Ministry of Higher Education (MOHE) and Universiti Teknologi Malaysia (UTM) in the form of a research grant number Q.J130000.2522.09H67 for this study is very much appreciated.

References

[1] Gunasekaran, K., Annadurai, R. and Kumar, P. 2012. Long Term Study on Compressive and Bond Strength of Coconut Shell Aggregate Concrete. *Construction and Building Materials*. 28(1): 208-215.

[2] Gunasekaran, K., Kumar, P. and Lakshmipathy, M. 2011. Mechanical and Bond Properties of Coconut Shell Concrete. *Construction and Building Materials*. 25(1): 92-98.

[3] Kaur, M. and Kaur, M. 2012. A Review on Utilization of Coconut Shell as Coarse Aggregate in Mass Concrete. *International Journal Of Applied Engineering Research*. 7(11): 05-08.

[4] Varghese, S., Kuriakose, B., Thomas, S. and Koshy. A. 1991. Studies on Natural Rubbershort Sisal Fiber Composites. *Indian J. Nat. Rubb. Res*. 4: 55.

[5] Rusbintardjo, G., Hainin, M. R., & Yusoff, N. I. M. 2013. Fundamental and Rheological Properties Of Oil Palm Fruit Ash Modified Bitumen. *Construction and Building Materials*. 49: 702-711.

[6] Sufian, Z., Aziz, N. A., Matori, M. Y., Hussain, M. Z., Hainin, M. R., & Oluwasola, E. A. 2014. Influence of Active Filler, Curing Time and Moisture content on the Strength Properties of Emulsion and Foamed Bitumen Stabilized Mix. *Jurnal Teknologi.* 70(4):135-141

[7] Oksman, K. and C. Clemons. 1998. Mechanical Properties Polypropylene-Wood. *Journal Of Applied Polymer Science*. 67: 1503-1513.

[8] Park, B.D. and J.J. Balatinecz. 1997. Mechanical Properties of Wood-Fiber/Toughened Isotactic Polypropylene Composites. *Polymer Composites*. 18(1): 79-89.

[9] Raj, R., B. Kokta, G. Groleau, and C. Daneault. 1989. Use of Wood Fiber as A Filler In Polyethylene-Studies on Mechanical-Properties. *Plastics and Rubber Processing and Applications*. 11(4): 215-221.

[10] Sahari, J. and S. Sapuan. 2011. Natural Fibre Reinforced Biodegradable Polymer Composites. *Reviews on Advanced Materials Science*. 30: 166-174.

[11] Sandi, A., D. Caufield, R. Jacobson, and R. Rowell. 1995. Renewable Agricultural Fiber as Reinforcing Fillers in Plastics: Mechanical Properties of Kenaf Fiber-Polypropylene Composites. *Ind. Eng. Chem. Res*. 34: 1889-1896.

[12] Sapuan, S. and M. Maleque. 2005. Design and Fabrication of Natural Woven Fabric Reinforced Epoxy Composite for Household Telephone Stand. *Materials & Design*. 26(1): 65-71.

[13] Yam, K. L., B. K. Gogoi, C. C. Lai, and S.E. Selke. 1990. Composites from Compounding Wood Fibers with Recycled High Density Polyethylene. *Polymer Engineering & Science*. 30(11): 693-699.

[14] Hainin, M. R., Matori, M. Y., & Akin, O. E. 2014. Evaluation of Factors Influencing strength of Foamed Bitumen Stabilised Mix. *Jurnal Teknologi*. 70(4) : 111-119

[15] Oluwasola, E. A., Hainin, M. R., & Aziz, M. M. A. 2015. Evaluation Of Asphalt Mixtures Incorporating Electric Arc Furnace Steel Slag And Copper Mine Tailings For Road Construction. *Transportation Geotechnics.* 2: 47-55.

[16] Kumar, A. and Swamy, R. 2011. Evaluation of Mechanical Properties of Al6061, Flyash and E-Glass Fiber Reinforced Hybrid Metal Matrix Composites. *ARPN Journal of Engineering and Applied Sciences*. 6(5):40-44.

[17] Prasad, S. and Krishna, R. 2011. Production and Mechanical Properties of A356. 2/RHA Composites. *International Journal Of Advanced Science And Technology*. 33: 51-58.

[18] Aigbodion, V., Hassan, S., Ause, T., and Nyior, G., 2010. Potential Utilization Of Solid Waste (Bagasse Ash). *Journal of Minerals & Materials Characterization & Engineering*. 9(1): 67-77.

[19] Bienia, J., Walczak, M., Surowska, B., and J. Sobczaka. 2003. Microstructure and Corrosion Behaviour Of Aluminum Fly Ash Composites. *Journal of Optoelectronics and Advanced Materials*. 5(2): 493-502.

[20] Prasad, N. and S. Acharya. 2006. Development and Characterization Of Metal Matrix Composite Using Red Mud an Industrial Waste For Wear Resistant Applications. *Development*.

[21] Bambogye, A. and Jekayinfa, S.O., 2006. Energy Consumption Pattern in Coconut Processing Operation. *Agricultural Engineering International*. VIII (the CIGR Journal Manuscript. EE 05 013).

[22] Shelke, A.S., Ninghot, K.R., Kunjekar, P.P., and Gaikwad, S.P., 2014. Coconut Shell as Partial Replacement for Coarse Aggregate: Review. *International Journal of Civil Engineering Research*. 5: 211-214.

[23] Nagarajan, V.K., Devi, S.A., Manohari, S., and Santha. M.M., 2014. Experimental Study on Partial Replacement of Cement with Coconut Shell Ash in Concrete. *International Journal*. 3(3): 651-661

[24] Madakson, P., Yawas, D., and Apasi. A., 2012. Characterization of Coconut Shell Ash For Potential Utilization In Metal Matrix Composites For Automotive Applications. *International Journal Of Engineering Science And Technology*. 4(3): 1190-1198.

[25] Olanipekun, E., K. Olusola, and O. Ata. 2006. A Comparative Study Of Concrete Properties using Coconut Shell And Palm Kernel Shell As Coarse Aggregates. *Building and Environment*. 41(3): 297-301.

[26] Frederick, T. and Norman, W. 2004. Natural Fibers Plastics And Composites. *EUA: Kluwer Academic Publishers*.

[27] Bhaskar, J. and Singh, V., 2013. Water Absorption and Compressive Properties of Coconut Shell Particle Reinforced-Epoxy Composite. *Journal of Materials Environment Science*. 1: 113-118.

[28] Munirah Abdullah, N. and Ahmad, I. 2012. Effect of Chemical Treatment On Mechanical And Water-Sorption Properties Coconut Fiber-Unsaturated Polyester From Recycled PET. *ISRN Materials Science*. 2012.

[29] Thaker, N., Srinivasulu, B., and Shit. S.C. A Study on Characterization and Comparison of Alkali Treated and Untreated Coconut Shell Powder Reinforced Polyester Composites.

[30] Dung, S.D., 2014. *Assessment of the Suitability Of Coconut Shell Charcoal As Filler In Stone Matrix Asphalt*.

[31] Ghani, W. W. A. K., Abdullah, M.F., Loung, C., Ho, C. and Matori, K., 2008. Characterization of Vitrified Malaysian Agrowaste Ashes as Potential Recycling Material. *International Journal of Engineering and Technology*. 5(2): 111-117.